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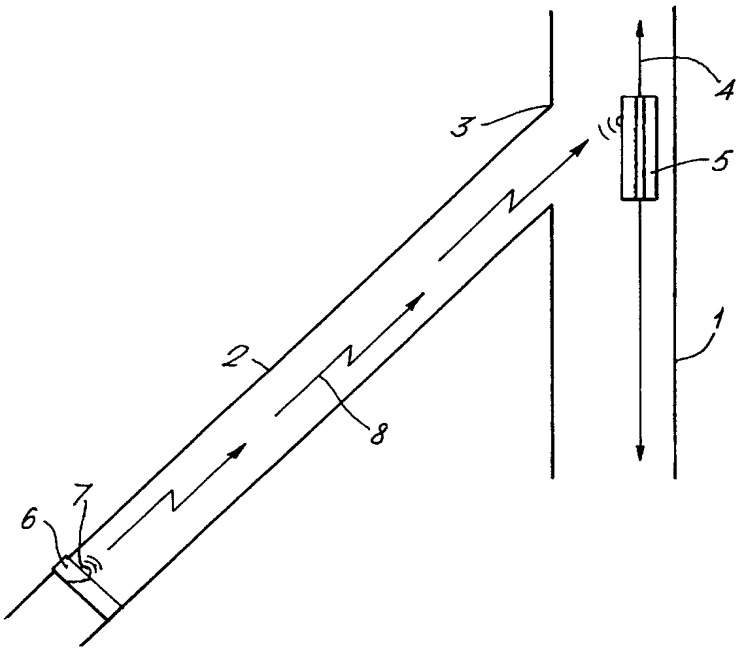
(54) Title: HYBRID WELL COMMUNICATION SYSTEM



(57) Abstract: A hybrid, hardwired (4) and wireless (8) well communication system comprises a fibre optical, electrical or other signal transmission conduit (4) extending from the wellhead into the well and one or more wireless signal transducers (7) that are located at a distance from the conduit (4) and transmit wireless signals (8) to one or more signal converters (5) which are coupled to the conduit, and which are located near branchpoints (3) of a multilateral well.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

HYBRID WELL COMMUNICATION SYSTEM

Background of the Invention

The invention relates to a hybrid well communication system and more in particular to a downhole system for transmitting signals in a hydrocarbon fluid production well.

Currently known well communication systems are either hardwired or wireless systems. Wireless systems are disclosed in US patents No. 4,893,644 and 5,706,896 and in European patent No. 646304 and have the disadvantage that the acoustic or electromagnetic signals transmitted through the well tubulars and/or fluids passing therethrough can only convey a limited datastream through the well and that the signal to noise level of the transmitted datastreams is low.

Hardwired downhole communication systems are able to transmit large datastreams with a high signal to noise level, but are extremely expensive and difficult to install and/or to modify and maintain after installation, in particular if the well is a multilateral well and the wires need to extend into different well branches.

The system according to the preamble of claim 1 is known from UK patent application GB 2340520. This prior art reference discloses an unbranched well having a horizontal inflow section in which a series of wireless signal transmitters transmit signals in a bucket-brigade mode to a signal receiver at the bottom of the vertical upper part of the well, where the received signal is transmitted via a signal transmission cable.

The known wireless signal transmitters transmit relatively weak acoustic or electromagnetic signals through the produced well fluids, which requires the use

of a series of transmitters along the length of the horizontal inflow region of the well. Such an arrangement would be impractical in a multilateral well since the signals transmitted in different well branches would interfere with each other.

The present invention aims to alleviate the disadvantages of the known system and to provide a cost effective and flexible well communication system which is able to transmit large datastreams at a high signal to noise ratio and which can be adapted easily after installation to changing circumstances and to various types of equipment that may be installed during the lifetime of a well, in case the well is a multilateral well and one or more well branches are added after drilling and completion of the original well in which a communication system has already been installed.

Summary of the Invention

The well communication system according to the invention comprises:

- a signal transmission conduit for transmitting signals between a control unit at or near the earth surface and a downhole signal converter;
- a downhole measuring and/or control assembly, which is equipped with a wireless signal transducer; and
- wherein said signal converter and signal transducer are located at different depths in the well and form a wireless communication link between said converter and transducer, and
- the well is a multilateral well comprising a main wellbore and one or more wellbranches;
- the signal transmission conduit extends from the wellhead into the main wellbore;
- at least one signal converter is located at or near a downhole branchpoint; and

- a measuring and/or control assembly, which is equipped with a wireless signal transducer is located in at least one wellbranch away from the branchpoint.

In such case the fibre optical or electrical signal transmission conduit in the main wellbore may serve as a backbone for the downhole communication network and a plurality of wireless radio communication links may form flexible extensions of the network which allow the downhole measuring and control equipment to be deployed and/or removed without requiring installation of additional wiring and making of cable connections downhole.

The signal transmission cable may be an electric or fibre optical cable. In the latter case the signal converter may comprise a piezo-electric or electromechanical signal transmitter at a well branchpoint and an acoustic sensor based on fibre-bragg or Fabry-Perot type sensor which is embedded in the fibre optical cable near said well branchpoint which transducer is adapted to transmit modulated acoustic waves to the acoustic sensor in response to wireless signals transmitted by the downhole wireless signal transducer. Alternately, the signal converter may comprise of an electro-optic converter wherein electrical signals are converted to modulated light and guided onto a single optical fibre and sent to the surface. Modulated optical signals from the surface are received by the signal converter, separated into distinct wavelength components using filters or diffraction gratings. The multiple wavelengths are then caused to fall on an array of optical detectors spaced according to the individual wavelengths to be detected and decoded. The multiple decoded signals are then encoded, multiplexed and transmitted to the downhole measuring and control equipment.

Description of a preferred embodiment

The invention will be described in more detail with reference to the accompanying drawings, in which:

Fig. 1 shows a multilateral well equipped with a hybrid well communication system according to the invention; and

Fig. 2 shows a multilateral well equipped with an alternative embodiment of a hybrid well communication system according to the invention.

Referring now to Fig. 1 there is shown a multilateral well having a main wellbore 1 and a branch wellbore 2, which wellbores intersect at a branchpoint 3.

The main wellbore is equipped with an electrical or fibre optical signal transmission conduit 4. This conduit 4 may be permanently embedded in a cement lining around a well casing or be arranged in an annular space surrounding a production tubing or be arranged inside a production tubing or liner as is illustrated in the drawing.

At the branchpoint 3 the conduit 4 is equipped with a signal converter 5. The branch wellbore 2 contains measuring and/or control equipment 6, such as a flowmeter, valve, formation or seismic sensor, which is equipped with a wireless signal transmitter 7.

The signal converter 5 and signal transmitter are each adapted to transmit and receive electromagnetic radiofrequency signals and thus form a wireless link 8 along a substantial part of the length of the branch wellbore 2. The signal converter 5 converts any wireless signals received from the transmitter 7 into equivalent electric or optical signals that are then transmitted via the conduit 4 to a measuring and control station (not shown) at the wellhead (not shown) and vice versa.

Referring now to Fig. 2 there is shown a multilateral well having a main wellbore 11 and a branch wellbore 12 which intersect at a branchpoint 13.

A fibre optical cable 14 extends through the main wellbore 11 and is equipped with multiple fibre bragg gratings 15 near the branchpoint 13, which gratings 15 reflects light with wavelengths equal to the grating width while all light of differing wavelengths continues to travel through the fibre optical conduit 14.

A piezo-electric transducer 16 is located at the branchpoint 13 and transmits modulated acoustic waves 17 to the fibre bragg gratings 15, which initiates variations in the wavelengths of the optical signal reflected thereby.

The piezo-electric transducer 16 is equipped with an antenna 18 which receives electromagnetic signals transmitted by a signal transmitter 19, such that the transducer 16 and transmitter 19 form a wireless electromagnetic link 20 in the branch wellbore 12. The transducer 16 and fibre bragg gratings 15 form a wireless acoustic communication link at the branchpoint 13, whereas the fibre optical cable 14 forms the hardwired communication link in the main wellbore 11. Various wellbranches may be equipped with wireless communication links as described hereinbefore which may be linked to the fibre optical cable with various piezo-electric transducers 16.

In the event that the signal converter is optically connected to the fibre optic cable (or electrical cable), optical signals may be separated into a plurality of constituent wavelength components using appropriate filters, mirrors and diffraction gratings. The multiple wavelengths are then caused to fall on an array of optical detectors spaced according to the individual wavelengths to be detected and decoded. The multiple

decoded signals are then encoded, multiplexed and transmitted to the downhole measuring and control equipment.

C L A I M S

1. A downhole communication system for transmitting signals in a hydrocarbon fluid production well, the system comprising:

- a signal transmission conduit for transmitting signals between a control unit at or near the earth surface and a downhole signal converter;
- a downhole measuring and/or control assembly, which is equipped with a wireless signal transducer; and
- wherein said signal converter and signal transducer are located at different depths in the well and form a wireless communication link between said converter and transducer,

characterized in that

- the well is a multilateral well comprising a main wellbore and one or more wellbranches;
- the signal transmission conduit extends from the wellhead into the main wellbore;
- at least one signal converter is located at or near a downhole branchpoint; and
- a measuring and control assembly, which is equipped with a wireless signal transducer is located in at least one wellbranch away from the branchpoint.

2. The system of claim 1, wherein the multilateral well comprises a plurality of wellbranches, which each contain a measuring and control assembly which is equipped with a wireless signal transducer and wherein the signal transmission conduit comprises a plurality of downhole signal converters, which are located at or near the well branchpoints.

3. The system of claim 1, wherein the signal transmission conduit is a fibre optical cable.

4. The system of claim 3, wherein the downhole signal converter is adapted for converting wireless signals into optical signals that are transmitted through the fibre optical cable and vice versa.

5. The system of claim 4, wherein the signal converter comprises a piezo-electric signal transmitter at a well branchpoint and a fibre-bragg or fabry-perot acoustic sensor which is embedded in the fibre optical cable near said well branchpoint which transducer is adapted to transmit modulated acoustic waves to the acoustic sensor in response to wireless signals transmitted by the downhole wireless signal transducer.

6. The system of claim 4, wherein the signal converter comprises an integrated electro-optic device that is directly connected to the fibre optic cable.

7. The system of claim 1, wherein the downhole signal transducer and converter are adapted to communicate with each other via transmission of electromagnetic signals.

8. The system of claim 1, wherein the signal transmission cable is an electric cable.

9. The system of claim 7, wherein the downhole signal transducer and converter are adapted to communicate with each other via transmission of electromagnetic signals through the wall of a branch well tubular that extends through at least part of the length of the branch well.

10. The system of claim 9, wherein the branch well tubular is electrically isolated from the casing and/or other well tubulars that are arranged in the main wellbore.

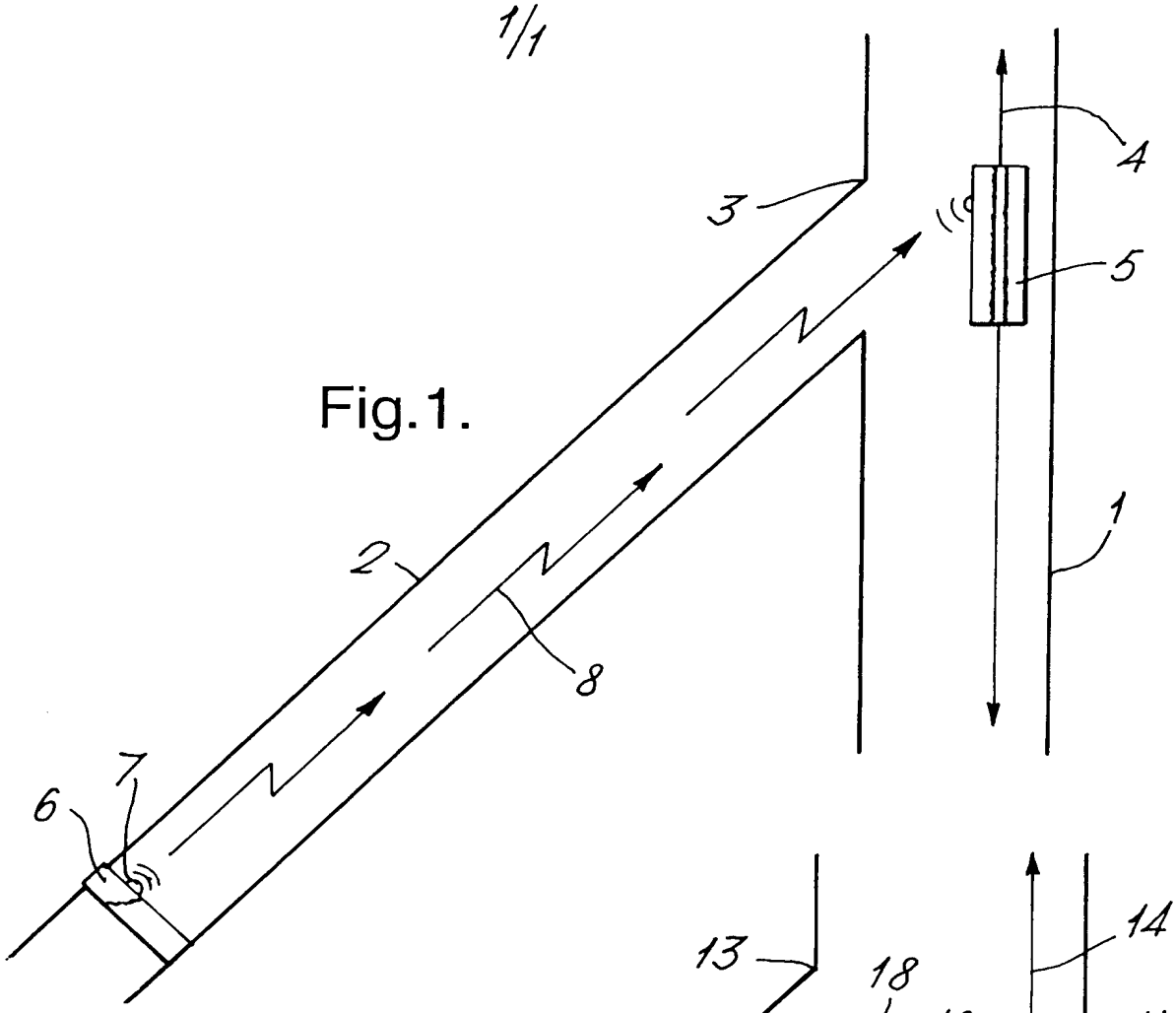

Fig.1.

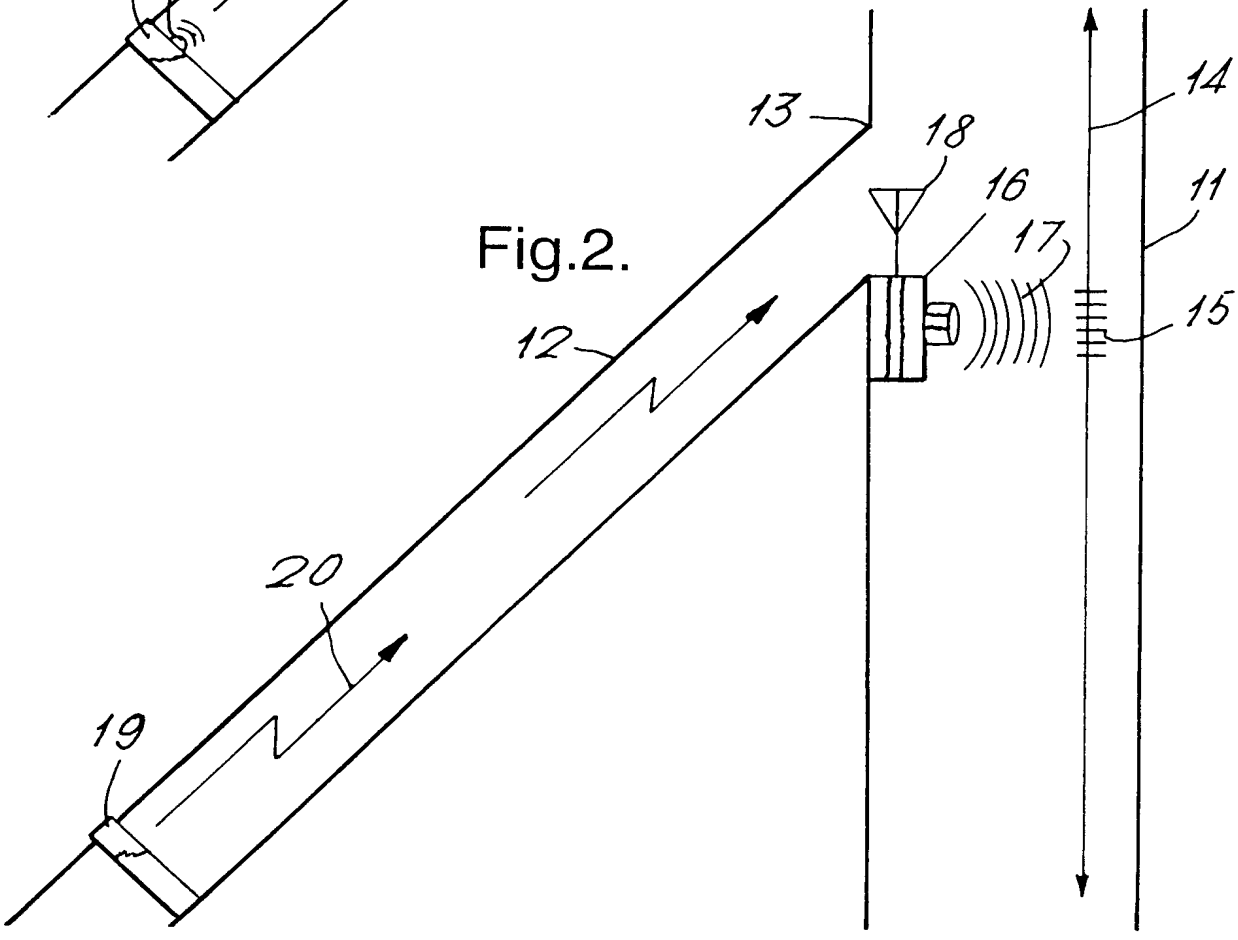

Fig.2.

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B10/12 E21B47/12 E21B47/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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